AN

EXPERIMENTAL INQUIRY

OF THE

GENERAL NATURE OF INFLAMMATION.

BY

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EXPERIMENTAL INQUIRY, &c.

INFLAMMATION, in its multifarious forms, is a daily occurrence in medical practice; it is surely, therefore, incumbent upon us to endeavour to elucidate some of those circumstances in its history which have not yet been explained. But as the blood vessels are the agents by which most of those changes in an inflamed part are effected, it is quite clear, that a rational pathology of inflammation must rest on a previous knowledge of their healthy functions.

The points on which physiologists differ most, are the kind and degree of contractility possessed by the blood vessels. It is more important to have these determined, since the most opposite opinions respecting them are held by men whose distinguished talents claim the greatest respect.

In discussing the contractility of the blood vessels, much difficulty has arisen from the indefinite expressions employed by writers. It therefore seems absolutely necessary, in the first place, to

make a few observations on certain terms which are become familiar in treating on this subject, and which are not always used with accuracy, nor, perhaps, in the same sense. The terms alluded to are irritability, sensible organic contractility, insensible organic contractility, and tonicity.

Haller, as is well known, after unwearied assiduity in experiments, published two essays on the sensible and irritable parts of animals, which have been the foundation of all our knowledge of irritability. In these experiments he paid attention to the degree in which living parts contracted on the application of stimuli, and hence deduced the intensity of this property in the several parts.

Bichat, aware of the obscurity which hung over this subject, endeavoured to render the knowledge of the vital actions more precise, by dividing contractility into animal and organic. The former he describes as essentially subject to the will, and having its principle in the brain, and its exclusive seat in the voluntary muscles; the latter, as having its principle in the moving organ itself, and as being a stranger to the influence of volition, and as giving rise to the phenomena of digestion, circulation, secretion, absorption, and nutrition. But, that he may be still more accurate in his account of the contractile power, this indefatigable physiologist makes two subspecies of organic contractility; sensible, and insensible. The former, he thinks, is exemplified in the visible actions of the heart, stomach, and intestines; whilst the latter

belongs to the excreting tubes, and is evinced in their action on the fluids contained in them. These two subspecies of organic contractility do not arise from different principles; the one is but the extreme of the other, and these extremes are connected by insensible gradations. These gradations are well marked in the circulating system, where the heart and the capillary vessels form the two extremes of contractility, and the larger blood vessels are the mean between them. Irritability, he believes, is not peculiar to muscle. It is true, muscles possess the maximum of organic contractility, but every living organ acts as they do, though in a manner less apparent, upon the excitant, when artificially applied, or on the fluid, which, in the natural way, is carried to it for the purpose of supplying the matter of secretion, nutrition, exhalation, or absorption*.

It appears, from this short sketch, that Bichat maintained there was a difference in kind between the animal and organic contractility; but by sensible and insensible organic contractility he only understood different degrees of the same property.

Dr. Parry has more lately treated on the arteries, and has used the term tonicity to express their vital power. "This power," he observes, "is, however, so far different from that which "in muscles is called irritability, that an artery

* Physiological Researches on Life and Death, by Bichat, translated by Good.

"suffers no degree of contraction from a great "variety of chemical and mechanical agents, called "stimuli; for none of these substances, applied to "any part of an artery, will cause it to contract*." This able physician also observes, that he intends by it to denote "a mean state of contraction ex- "isting during health, and capable of being in- "creased by certain causes, and of being dimin- "ished or lost by certain diseases."

It would appear, therefore, that Haller, and the other writers quoted, concur in using irritability to express that vital power in any living part, by which it contracts or shortens its fibres when touched by a stimulus. In this sense it is also used by the celebrated Hunter, and others of great note; and in this acceptation it is employed in this Inquiry.

Having endeavoured to fix the precise acceptation of those terms which are used to express the vital power of the blood vessels, the next object is to determine whether they assist in the circulation of the blood.

At first sight it appears strange, that, although nearly two centuries have elapsed since the brilliant discovery of the circulation of the blood, it yet remains to be decided what part the heart performs in that important function: but when we more closely examine the nature of the problem to be solved, we see the intricacies of the subject,

* Parry on the Pulse, page 52.

and are enabled to appreciate the difficulties which human genius has had to contend with, in endeavouring to explain the offices of this organ.

It is thought by some writers that the contraction of the ventricle is alone adequate to circulate the blood; others, on the contrary, believe that the blood vessels possess an inherent irritability, by which they contract on the blood, and preserve the impulse which at first gave it motion. The supporters of the latter hypothesis are numerous, and names of the highest repute sanction this view of the question. Independently of all other considerations, they conclude that the immense force with which the blood must be propelled from the heart, to enable it to permeate the myriads of small tubes through which it has to pass, would require such an amount of contractile power as could hardly be conceived to exist in that organ.

In discussing this point, therefore, writers have always had recourse to both a negative and positive mode of proving a contractile power in the blood vessels. They have shown that the heart is not adequate to the circulation of the blood; and, by experiments on living animals, have demonstrated a vital contractility in the arteries and veins.

In order to calculate whether the impetus with which the blood is thrown from the ventricle into the aorta, is sufficient to distribute it to those millions of minute and remote vessels through which it has to pass, before returning by the veins to the

right auricle, it is necessary to assign the precise force with which the blood is impelled into the great artery, and also the exact momentum any given column of blood should receive at the heart to enable it to circulate, with the wonted celerity, in a minute capillary tube, unassisted by any contraction in the blood vessel. But, unfortunately, even an imperfect knowledge of either of these necessary steps in the investigation is not to be obtained ; for, among those who have endeavoured to ascertain the sum of the heart's action, there is such glaring contradiction, that no reliance can be placed on their calculations. Dr. Whytt's opinions on this subject were founded on Dr. Hales' experiments ; and he believed that the real remaining force of a globule of blood, when arrived at a red capillary vessel, was not equal to its own weight. At any rate, the motion of the blood, under such circumstances, must be very slow.

But so far from finding the motion of the globules very slow in the minute vessels, which must necessarily happen if the heart were the sole agent in the circulation, actual experiments demonstrate that these globules glide along with considerable rapidity ; with so great rapidity, indeed, that, when magnified by the microscope, the eye can scarcely follow them. Verschuir observed this in his experiments*; and Dr. Thomson found the globules moving so briskly, that it was with difficulty

* Verschuir de Arteiarum et Venarum Vi Irritabili, p. 9.

he followed them through any determinate space†, and in experiments on frogs the author of this Inquiry has frequently observed the same thing.

In every rational investigation wherein it is impossible to arrive at any positive evidence, we should incline to that side of the question which appears most consistent with facts. In this view of the subject, the idea of the impulse given to the blood by the ventricle being the sole cause of its motion, to say the least, seems very questionable.

It is the consideration that the contractile power of the ventricle is inadequate to the circulation of the blood, which has induced some late physiologists to take a new view of the functions of the heart. Dr. Wilson, Dr. Carson, and others, are anxious to establish the fact, that a dilatation of the chambers of the heart follows their contraction, by which a tendency to vacuum is formed for the veins to unload themselves. They are not, however, agreed as to the mode in which this tendency is produced; some of them contending that the structure of the heart is alone adequate to the purpose, whilst others think the assistance of the elasticity of the lungs necessary.

Dr. Carson ranks amongst the latter. After having explained the effect which a dilating power in the chambers of the heart would have upon the motion of the blood, he says: "In searching for "the causes by which the chambers of the heart

† Thomson on Inflammation, p. 79.

"were dilated after contraction, it was ascertained, that this condition of the organ was, in part, "to be ascribed to the form and position of its "fibres; in consequence of which, simple relaxation was accompanied by a certain degree of "dilation, but particularly to the supporting of a "part of the atmospherical pressure that would "have rested on the convex surfaces of the heart, "or its envelope, by the resilient or collapsing "effort of the lungs*."

This view of the subject is highly ingenious, and is supported by the writer with perspicuity. But it is only in the more perfect animals that this cause can be supposed to influence the motion of the blood, because, in many of the inferior animals, the lungs are so situated, and so devoid of elasticity, that they cannot affect the motions of the heart. Besides, in the fœtus, the motionless state of the lungs altogether prevents any such co-operation.

Dr. Carson endeavours to obviate this difficulty, by substituting the action of the diaphragm for that of the lungs; but this supposition is quite gratuitous, and unsupported by any proof.

Hence, Dr. Carson's theory of the circulation is only applicable to some classes of animals, and leaves us in the same perplexity with regard to the motion of the blood in the most numerous of the animal kingdom. If Dr. Carson's view of the

* Carson on the Motion of the Blood, p. 147.

circulation were not beset by the difficulties which have been stated, it would still behove us to inquire how far facts, relating to the venous circulation, support his opinions.

Those writers who regard the heart as a suction pump, conceive that "the main support and preservation of a venous current of blood to the heart depends upon a vacuum being momentarily provided where the veins may unload themselves*." If the main support of the venous current depended on a tendency to a vacuum being momentarily produced in the heart, it is quite evident that the motion of the venous blood could not be in a continued stream; it would move much more quickly during its diastole of the auricle than during its systole, because it is only during the dilatation of the auricle that the principal cause of the venous circulation operates. But the microscope shows us that the blood in the veins moves rapidly, in an uninterrupted stream, without its motion being at all quickened during the dilatation of the auricle. Other facts may be stated equally hostile to the hypothesis.

If a ligature be applied to a vein, the blood accumulates, which should not happen if the tendency to vacuum at the heart gave rise to the circulation in the veins, because the gravity of the blood, according to the view of Dr. Carson, should direct it onwards, through the numerous anasto-

* Wilson on the Moving Powers employed in the Circulation, p. 35.

mosing vessels, towards the auricle, where all atmospheric pressure, during its diastole, is removed.

From this reasoning, and from a consideration of the evidence by which Dr. Carson attempts to prove that a tendency to vacuum is formed in the heart, the author is induced to believe, that the ingenious arguments brought forward by that gentleman in support of his theory, have given it a plausibility to which the facts already ascertained do not, by any means, entitle it. Indeed, the knowledge we at present possess, so far from countenancing such opinions, seems completely at variance with them.

With regard to the direct evidence by which the contractility of the blood vessels is supported, this branch of the inquiry presents itself under the following heads :—

I. The consideration of the facts relating to the larger arteries.

II. The description of those phenomena which are observed in the capillary vessels.

III. The notice of those appearances which favour the supposition that the veins are not devoid of an active contractility.

I. As to the facts connected with the larger arteries, it may be necessary to give a short previous description of their three coats.

The exterior, called by Haller the tunica cellulosa propria, is the firmest and most dense of the three ; it is also the whitest in colour. The prin-

cipal power of resistance is derived from this coat; it is very elastic, and is composed of condensed cellular membrane, externally more lax, internally more and more compact.

The middle coat is composed of many firm dense fibres, which are disposed in strata around the arteries; they are of a fleshy nature. Monro, Haller, Ludwig, and many others, agree in calling this coat muscular. Monro remarks, that "What "really deserves to be called the first proper "coat of the arteries, is the muscular, or ten- "dinous, which, in the human body, at least, "consists of auricular fibres connected strongly "together*." Haller also calls them fleshy fibres, and says they possess every requisite for muscular action†.

But there are other eminent writers, who conceive that the structure of this coat does not at all resemble muscle, and that it only possesses an elastic property. Haller and Ludwig mention several authorities; and Bichat and Berzelius have since maintained a similar doctrine.

Bichat has compared the changes which this coat undergoes by the action of various agents, with those which parts confessedly muscular undergo when acted on by the same agents. He has found that the changes manifested in these two

* Monro, primus in the Edinburgh Med. Essays and Observations.

† In arteriis majoribus musculosam carnem descripsi, nihilque abesse volui quo musculi polleant. Halleri Opera Minora, p. 490.

cases are by no means similar, and hence derives the non-muscularity of the arteries*. The total inapplicability of this reasoning is evident from the great diversity which is displayed in the structure of muscles in different animals. How little, for example, does the nature of those muscles which enable the swift hare to evade the chase of its pursuers, resemble the structure of those by which the sluggish snail slowly transports its little tenement over the small space of ground it is destined to travel.

Berzelius, in his inquiries, has had recourse to chemical analysis, and, by the most cautiously conducted experiments, has not detected any fibrine in the middle coat. Hence he concludes, that this coat cannot act as a muscle†. But the force of this argument is completely lost, when it is recollected that the muscles in the same animal differ much in structure, according to the office they have to perform. This obviously appears when we compare the fibres of the deltoid muscle with those of the urinary bladder, of the stomach, and of the intestines. Moreover, the uterus, which of all parts in the body evinces the most powerful contractility, has never been shown to possess fibres similar to those which are demonstrable in the muscles of voluntary motion.

* Elle forme un tissu à part dans l'économie, tissu qui a des caractères exclusivement distinctifs. Anatomie Générale, vol. 2, p. 283.

† Berzelius on Animal Chemistry.

From what has been stated, it appears that irritability resides in parts, the fibres of which differ widely from each other: the fibres, indeed, seem to vary with the nature of the contraction they have to perform in their respective organs. Embracing, therefore, this view of the subject, the author is inclined to regard the pale red fibres which encircle the arteries, and constitute their middle coat, as admirably suited, by contracting on the contained fluid, to lessen the calibre of the vessel, and that they are such as may be expected in a canal which is intended to exercise a variable contractility.

The inner coat, lining the cavity of the arteries, is highly polished and smooth, and is connected to the middle coat by cellular substance.

Having considered the structure of the larger arteries as much at length as seems necessary in this Inquiry, the question follows, In what manner are they affected by stimuli? Many eminent men have contributed to our knowledge on this subject. Amongst others, we cannot pass unnoticed the works of Becquet,* Gorter,† Glisson,‡ and Senac. The treatise of the latter, on diseases of the heart, contains many valuable facts which bear upon this point. He says, "Leiz l'aorte et pincez "la, elle fremit, elle se met en contraction: tous "ces armeaux après la mort même conservent cet

* Dissertationes Anatomicæ.

† Exercitationes Medicæ de Motu Vitali.

‡ De Ventriculo.

" agent ou ce mobile qui anime le cœur ; quand " les chairs des animaux palpitent, les canaux ar- " tériels palpitent de même ; qu'on les dépouille " des chairs qui les environnent, on y verra de " mouvemens alternatifs, l'irritation augmente ces " mouvemens et les entretient."*

Haller seems to have doubted whether he should refer the arteries to the class of irritable parts. In his Essay on Irritability he declares, that although he cannot absolutely deny the irritability of arteries, yet he does not at all see that it is confirmed by experiments. Notwithstanding this declaration, in his *Elementa Physiologiæ* he states that the larger arteries are in some degree irritable.†

The famous Zimmerman, who was the disciple of Haller, published an inaugural dissertation on irritability. He relates in it three experiments on the arteries of dogs,‡ in which he applied sulphuric acid to the denuded vessels, and in two of the three examples contraction was produced. He attributes the non-contraction in the last case to the weakened state of the animal ; and he adduces this as a strong presumptive proof that the contraction in the two others was not produced by the corrugation of the acid. Besides the testimo-

* Senac, Traité de Structure du Cœur, p. 227.

† Hæc ità decet proponi, ut ne suprà verum aliquid addamus.—Musculosas arteriarum majorum fibras distentas se restituere non est dubium ; neque carnem naturam suam contractilem hic deponere æquum est suspicatu.—Halleri Elementa Physiologiæ, tom. ii.

‡ Zimmerman de Irritabilitate, p. 24.

ny of these writers, Dr. L. Bikker* and J. J. Vandembos† affirm that they detected perfect irritability in the aorta by the electric aura; and Van Geuns asserts that he saw, when this stimulus was applied, so much motion in the carotid, that no doubt remained with him of its possessing a muscular power. But of all our predecessors, Verschuir is the most accurate on this point. His thesis contains most unanswerable results. He has related twenty-one experiments, which he performed on the larger arteries of dogs and other animals. In all of them, after dissecting away the integuments covering the arteries, he irritated the vessels with a scalpel, and observed whether any contraction was produced.

The following is an abstract of those experiments. In four he could not detect indications of irritability, although he applied various stimuli to the arteries.‡ In six instances the effect was not sufficiently evident for him to determine whether it should be attributed to the irritable property, or to some other cause.§ His mind, therefore, remained doubtful for some time; but when, from other more decisive experiments,¶ in which every caution to avoid error had been employed, the

* Dissertart. de Naturâ Humanâ, p. 45.

† Dissertatio de Vivis Humani Corporis Solidis. In App. Exp. 10.

‡ Verschuir de Arteriarum et Venarum Vi Irritabila. Exp. 12, 15, 20, 21.

§ See Experiments 2, 3, 4, 10, 11, 19.

¶ See Experiments 1, 5, 7, 8, 9, 13, 16, 17, 18, 19, 20.

most satisfactory proofs of irritability appeared, he ceased to think the result of the six experiments at all doubtful. He adds that these experiments were witnessed by several friends ; and in one instance the effect of the stimulus was so manifest, that the most sceptical must have been convinced of the existence of an irritable property in the arteries. We may judge how deeply he was impressed with a conviction of the action of the artery, from the strong metaphorical language he uses to express himself on that occasion. "Quasi nunc demum penitus percipiens stimuli molestiam."*

* As this Dissertation is little known, it may be no unacceptable addition to what has been said to subjoin the following conclusions of the writer referred to. "Varios vidi in his ex-
"perimentis eventus. In nonnullis nulla manifesta irritabili-
"tatis et contractionis signa, licet variis stimulis arterias irri-
"tarem, detegere potui : in aliis res non adeò manifesta fuit
"ut dubius hærerem, nùm quidem ille effectus principio ir-
"tabili tribui beberet, an potius alii cuidam causæ : neque
"hæc mihi satisfecerunt, ut absque scrupulo culcalum adfir-
"manti sententiæ adjicere auderem, cùm autem sæpius idem
"omni adhibita cautela, viderem, cùm luculentiora iis irrita-
"bilitatis indicia observarem, majorem vim probandi arteria-
"rum irritabilitatem adquisiverunt. Expertus enim sum ad
"irritationem, ope stimuli ferrei in arteriis contractiones quas
"non solùm ego, sed et Amici et socii mecum viderunt. Gau-
"deo in primis hæc confirmari auctoritate cel. Van Doeve-
"ren, viri naturam consulere soliti, peritissimi, qui quidem
"his experimentis quandoque adesse voluit. Leviter radendo
"et comprimendo ope scalpelli et tenaculi, arteriam contrahere
"vidi non unà, sed iteratis vicibus ; manifestissimé semel,
"dùm attentus eram ad mutationem ex irritatione in arteria

Verschuir's experiments, though now seldom adverted to, drew attention when they were published. Dr. Dennison, in his Inaugural Dissertation, has taken advantage of them, and supports his arguments for the irritability of the arteries by the facts brought forward by that writer. In addition to those described by Verschuir, he relates four experiments made by himself, in two of which he detected irritability in the arteries*. But the labours of Mr. John Hunter, in whose accuracy we may place unlimited confidence, unequivocally tend to prove the irritable power of the blood vessels. No one can peruse his excellent work on inflammation, without feeling the force of the facts and reasoning by which he supports this view of the subject†. He states, among other experiments, that having laid bare the posterior tibial artery of a dog, he observed it to be so much contracted in a short time, as almost to prevent the blood from passing through it, and when it was divided the blood only oozed from the orifice. This fact is confirmed by Dr. Fowler, who in his thesis gives us experiments on the arteries in the

"ortam, observavi hanc partem esse contractiorem, ac ante "fuerat: momento cùm hunc effectum inspexeram, in arteria "eodem illo loco longé arctiùs ac adhuc fuerat (quasi nunc "demùm penitus percipiens stimuli molestiam) ante oculos "sese constrinxit, adeò clarè, adeò dilucidè, ut nullum dubium "de irritabilitatis effectu restaret."—*Verschuir de Arteriarum et Venarum Vi Irritabili.*

* Dr. Dennison de Vasorum Irritabilitate.

† Hunter on the Blood, Inflammation, &c.

ears of rabbits, in which very similar results ensued*. But to quote all the testimony in favour of the irritable power of the arteries would be superfluous; it will be sufficient for the present purpose to mention such authorities as are in the greatest estimation. Even the works of Bichat, who is the decided opponent of those who have contended for the irritability of the arteries, contain facts which favour this supposition. How are we otherwise to account for the manifest contraction of the arteries under chemical stimuli, observed by him? Will the cool and dispassionate judge be content with Bichat's feeble attempt to evade this conclusion, by declaring that it proceeded from the "racornissement" of the vessel? This racornissement, or corrugation, never takes place so as to lessen the caliber of the vessel in any great degree. This appears to be an attempt of a kind not very unfrequent in the works of that celebrated physiologist, to offer such an explanation of a fact as may support some favourite hypothesis.

Dr. Jones, in his excellent work on hæmorrhage, ably combats the hypothesis of elasticity being the sole agent in the contraction of the large arteries; and adduces instances in which exposure to the air produced so much contraction as to prevent the pulse being felt or seen, although when

* Disputatio Inauguralis de Inflammatione.

the artery was first exposed dilatation and contraction of the vessel had been very evident*.

In this place, some comments may be offered on the late publication on the pulse by Dr. Parry, noticing those experiments which are by some supposed to demonstrate that the arteries are not irritable: for that learned author, from whom it is necessary again to quote, conceives that the facts he adduces shew "that the vital power possessed "by the arteries is so far different from that "which in muscles is called irritability, that an "artery suffers no degree of contraction from a "great variety of chemical and mechanical agents, "called stimuli; for none of these substances, ap-"plied to any part of an artery, will cause it to "contract." Hence, as was before observed, he is inclined to attribute a power of another kind to the arteries, which he calls tonicity. We quarrel not with the term, provided the experiments demonstrate any new faculty in the vessels, or invalidate the testimony of other writers on this point; but, in attending to the history of these cases, it will be found to speak a language quite plain and intelli-

* Insuper arteriæ aëri expositio necessaria, contractionem quandam creat, quæ stimulorum mechanicorum effectum haud parùm imminuet, si non ominò irritum reddet; nam certum est, et sæpè in experimentis in canibus institutis observavi, arterias etiàm magnas, quæ, quùm primùm aëri exponuntur, tam oculo quam manu pulsare manifestè observantur, brevi admodùm tempore interjecto, neque oculo, neque tactu moveri percipi posse, sive id ad animalis terrorem et dolorem, sive ad frigoris effectum, sive ad utramque causam, sit referendum. —*Jones de Arteriæ Sectæ Consecutionibus, p.* 29.

gible, and manifestly to support the opinion here advanced relative to the action of the arteries.

Dr. Parry does not seem to allow that he applied any stimulus to the vessels, during their exposure; nor, in his reasoning on his experiments, does he advert to the unnatural circumstances under which his observations were made; which circumstances must, however, necessarily have influenced the result. Some of his experiments seem, indeed, to lead to a train of reasoning very different from that which he adopts; particularly the 13th, the 24th, the 26th, and the 27th. In the 13th, a contraction was produced by denuding the carotid artery; also, in the 24th, after the left carotid artery had been exposed for half an hour, it was found, by accurate measurement, to have diminished in caliber nearly one-third. The 26th is still more remarkable, for in that instance the carotid artery, when exposed, was $\frac{210}{400}$ of an inch in circumference, but it almost immediately shrunk through the whole space which was exposed, so as to become, in circumference, only $\frac{188}{400}$ of an inch At the same time, a portion of the artery which had been more recently exposed was $\frac{254}{400}$ of an inch. The circumstance of the great diversity of diameter in contiguous portions of the same artery, as demonstrated in this case, according to the longer or shorter application of the air and other irritating substances, seems to prove that the degree of contraction in the fibres of different portions of the same vessel was in proportion to the intensity

of the stimulus applied, and the time of its application. Nor was this a solitary example of the great variation of diameter in the arteries when exposed; for in the 27th experiment it is expressly stated, that that portion of the artery which had been exposed was found to be much less than the part above or below it.

The additional experiments lately published by Dr. Charles Henry Parry are still more conclusive. In the 4th experiment, it is observed, that "before any diminution of size had taken place "from exposure or irritation, it was evident that "no alternate dilatation or contraction of the artery "existed. In ten minutes after exposure, there "was an evident contraction of the artery." In the 5th he says, "the left carotid was exposed. Im- "mediately on exposure, the circumference of the "artery was $\frac{350}{400}$ of an inch. In fifteen minutes "the artery measured $\frac{385}{400}$ of an inch, having lost "$\frac{265}{400}$." In the 7th experiment it is remarked, that "a saturated solution of common salt was "then applied. In four minutes the circumference "became $\frac{372}{400}$ of an inch. After washing off the "salt, the liquor ammoniæ carbonatis was again "applied, and in four minutes the artery measured "$\frac{300}{400}$, suffering a loss of $\frac{72}{400}$ of an inch.*"

Let us inquire in what respect these results differ from those that would have taken place in

* Additional Experiments on the Arteries, by C. H. Parry, M. D. F. R. S. p. 7, 10, 13.

a part which is acknowledged to possess the faculty of irritability, under like circumstances. If we open the abdomen in a living animal, and observe the intestines, are they not spasmodically contracted? and is not this attributed to the action of the unnatural stimulus on the muscular fibres of the intestines? and in what respect does this contraction differ from that observed by Dr. Parry in the cases above quoted? For the most strenuous supporter of tonicity cannot deny, that in separating an artery from its coverings, exposing it to the air, and measuring it with instruments, Dr. Parry necessarily subjected it to the action of stimuli. He must also admit, that those stimuli produced a shortening or contraction of the circular fibres of the middle coat; for in the 26th experiment, the circumference, in the first instance, was $\frac{210}{400}$ of an inch. Now Dr. Parry himself admits, in the 52d page of the treatise alluded to, that the shortening or contraction of a fibre, by the application of a stimulus, is the best evidence that can be given of its being irritable.

The irritability of the arteries seems therefore to be proved by the experiments of Dr. Parry and his son, who contend that they possess no such property.

On the whole then it appears, from the review of the opinions of various authors, that the testimony is decidedly favourable to the irritability of the larger arteries. At the same time it should be recollected, that in all disputed subjects we should

not so far depend on the observations of those who have gone before us as to admit further inquiry. The author, therefore, will submit to the reader's judgment an account of some experiments which he has himself made, and the deductions to which, in his opinion, they lead. As many of them were similar in their results, those which have a near resemblance shall be arranged under distinct classes; and one of the most satisfactory experiments of each class shall be fully related, so as to give a precise idea of its nature and effects. The remainder shall be exhibited in a short tabular form. This arrangement will comprehend four classes.

1. *Slight Contraction.*—By this the fact is expressed, that a part of the vessel, in length not more than the thickness of a thread, became much smaller than the part above or below, and remained in that state sometimes for a minute, sometimes for nearly half an hour.

The femoral artery of a cat was exposed, and scraped with a scalpel. During the first twenty minutes no visible effect was produced; but after that time, the contractions and dilatations were clearly perceptible, and in half an hour a slight permanent contraction occurred, which continued until the experiment was closed.

2. *Extensive lasting Contraction.*—In the instances of this kind, a portion of the vessel from a quarter of an inch to two inches in length, became smaller than the parts of the vessel above or below, which contraction generally lasted from a minute to a quarter of an hour.

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The femoral artery of a dog was exposed, and a ligature passed around it so as to embrace it closely without diminishing its diameter. The vessel was irritated with the point of a scalpel, and an increase of pulsation was several times produced. Whenever the irritation was omitted, the motion of the vessel returned to the state it was first in. In about a quarter of an hour after the commencement of the experiment, the pulsation ceased to be visible, and the vessel appeared contracted, the ligature having become lax. A second ligature was now drawn, as the first had been, closely around the artery. The two ligatures were then removed and measured. The length of the first ligature was 0·7 of an inch; that of the second, 0·6 of an inch.

3. *Irregularity of Surface in the exposed Artery.*—In this result, the vessel, which when

first exposed had been smooth and even, became unequal, as if composed (like the trachea) of rings; which irregularity appeared to arise from the permanent contraction of the fibres of the middle coat.

EXPERIMENT.

The femoral artery of a cat was exposed, and irritated with the point of a scalpel. In about a quarter of an hour, the artery, which at first had felt smooth and even to the finger, became uneven and annulated.

4. *Great increase of Motion in the part of the Vessel irritated,* which immediately succeeded the application of the stimulus.—This increase of motion did not arise from any modification of the heart's action; for the degree of dilatation and contraction in the unirritated part of the vessel nearer the heart was unaltered.

EXPERIMENT.

The abdomen of the full grown rabbit was opened, and the aorta exposed. The pulse was perceptible, but not very distinctly so; neither could those present say, positively, that there was

lateral dilatation. Liquor ammoniæ was applied to the artery : its motion was perceptibly increased by it ; and a second application of the stimulus being made, alternate dilatation and contraction were rendered very evident. A thread was then passed tightly around the aorta, and the ammonia again applied. The vessel during its dilatation, rose much more above the thread after the stimulus was applied than it had done before. Each application of the ammonia produced a similar effect.

TABLE I.

	Stimulus.	*Animal.*	*Part irritated.*	*Effects produced.*
1	Attrition	A Rabbit	Abdominal Aorta	After irritation had been applied 3 minutes the vessel contracted.
2	Attrition	A Cat -	Abdominal Aorta	In 5 minutes dilatation and contraction increased; in 7 minutes the vessel permanently contracted.
3	Attrition	A Dog -	Mesenteric Arteries	Pulsation at first increased; in 5 minutes permanent contraction.
4	Attrition	A Dog -	Femoral Artery -	Pulsation at first increased by the stimulus; in 13 minutes permanent contraction.
5	Attrition	A Cat -	Femoral Artery -	In 10 minutes, 1-2 an inch of the vessel permanently contracted.
6	Attrition	A Cat -	Small Artery - -	When first exposed did not pulsate, after 10 minutes' irritation, pulsation very perceptible.
7	Attrition	A Cat -	Femoral Artery -	In 1-4 of an hour the vessel became irregular from contiguous construction.
8	Attrition	A Cat -	Femoral Artery -	In 5 minutes the vessel contracted; the contraction lasted 10 minutes, then gave way, and dilatation and contraction became very perceptible, the vessel being moved in a tortuous manner.
9	Attrition	A Dog -	Femoral Artery -	In 5 minutes the vessel contracted; in 10 vermicular motion was produced.
10	Attrition	A Cat -	Femoral Artery -	Increased pulsation in the part irritated after each application of the scalpel.
11	Attrition	A Cat -	Femoral Artery -	In ¼ of an hour dilatation and contraction increased; in 20 minutes permanent contraction.
12	Attrition	A Cat -	Femoral Artery -	In 5 minutes pulsation rendered more perceptible.
13	Attrition	A Cat -	Femoral Artery -	In 15 minutes a ringlike appearance of the vessel; in 20 minutes tortuous movement.
14	Attrition	A Dog -	Femoral Artery -	Dilatation and contraction became more evident from the irritation.

TABLE I. *(Continued.)*

	Stimulus.	*Animal.*	*Part irritated.*	*Effects produced.*
15	Attrition .	A Dog	Femoral Artery .	In 5 minutes a ringlike appearance came on, and in 10 minutes the vessel moved in a tortuous manner.
16	Attrition .	A Dog	Aorta . .	Pulsation much increased by irritation.
17	AtmosphericAir	A Cat	Mesenteric Arteries	All these vessels, which on first opening the abdomen could not be seen to move, in 10 minutes became tortuous, and a vermicular motion was evident in them.
18	Atmospheric Air, & dissecting the Covering.	A Dog	Carotid Artery .	Permanent contraction came on in 5 minutes.
19	Ammonia .	The Rabbit	Abdominal Aorta	Contractions and dilatations immediately much increased.
20	Ammonia .	A Horse	The Carotid .	There was, when exposed, no dilatation during the systole of the heart; but, after the application of ammonia, dilatation and contraction became very evident.
21	Ammonia .	A Horse	The Carotid .	On first appearance no dilatation or contraction; the artery measured $\frac{5}{20}\frac{4}{0}$ of an inch in circumference; ammonia was applied, and the pulsation became visible; after three applications the vessel in one part contracted, and above it dilated; the following were the measurements—dilated part $\frac{6}{20}\frac{6}{0}$ of an inch, contracted part $\frac{5}{20}\frac{2}{0}$ of an inch.
22	Ammonia .	A Dog	Femoral Artery .	Pulsations became increased, and part of the vessels to which ammonia was applied, dilated; proved by the measuring of ligatures drawn closely around the vessel. The ligature before the ammonia was applied measured $\frac{1}{20}\frac{0}{0}$ of an inch, after application $\frac{1}{20}\frac{8}{0}$ of an inch.
23	Ammonia	A Dog	Aorta . .	Nearly a similar result.
24	Nitric Acid .	A Cat	Femoral Artery .	Contraction immediately produced; in 10 hours again looked at the artery. Contraction had disappeared. Chemical effect of acid visible.
25	Nitric Acid	A Dog	Aorta . .	Vessel contracted much. A ligature applied before application of nitrous acid, measured $\frac{3}{20}\frac{8}{0}$ of an inch; a ligature applied after acid measured $\frac{3}{20}\frac{1}{0}$ of an inch.

It now remains to be determined how far the results of these experiments tend to prove the irritability of the blood vessels. The coincidence of results with those of the writers above quoted, will best appear by comparing the effects produced under similar circumstances in these experiments and in those before alluded to. In instituting this comparison, the effects which arise from denuding the larger arteries may be first reviewed. On this point there is no diversity in the testimony of Hunter, Fowler, Jones, and the two Parrys. Each bears witness to a contraction frequently arising from the exposure of arteries; and in the author's experiments this was often seen to happen. In those examples in which the mechanical irritation with the scalpel was employed, we shall find abundant reason to acknowledge a uniformity of result. A contraction, which in some instances remained even after the apparent death of the animal, was a common effect of the stimulus in Verschuir's experiments. In the foregoing table many instances may be found in which this event ensued. An increase of dilitation and contraction in the exposed part of the vessel, whilst the stimulus was applied, is mentioned by Verschuir and Senac; and the experiments of the author prove this to be not an uncommon occurrrence. Verschuir speaks of a knotty appearance sometimes taking place in arteries when scraped with the scalpel.

This seems not to differ from the irregularity of surface described as a result in the experiments of the author, and as arising from the contraction of the fibres of the middle coat.

Zimmerman, Dennison, and Bichat, all agree that acids produce contraction; and the 24th and 25th experiments in the table are a confirmation of their evidence.

These authors then coincide in stating that exposure of an artery to the air excites contraction; that irritation with the scalpel produces a contraction, or increases the pulsation, or brings on an irregularity of the vessel, which may be felt with the finger; and, finally, that the application of the stronger acids to an artery causes contraction.

It is to be regretted that the effects which arose from the application of ammonia in the author's experiments do not correspond with those which Bichat has detailed, who denies the possibility of producing any contraction in arteries by means of alkalies. It is painful to oppose one whose experimental accuracy is so generally admitted; but the results of the author's experiments are given as they occurred, and as they impressed those friends who assisted him in making them. In one experiment, an artery was proved by admeasurement to be one-eighth less in circumference after the application of the ammonia than it had been before. In other examples the ammonia pro-

duced an opposite effect. From the violence of the stimulus the irritability of the artery was suddenly diminished, and a dilation of the vessel ensued. In other examples it very much increased the action of the vessels; for arteries, which when first exposed scarcely pulsated, were very evidently contracted and dilated immediately after being touched by the liquor ammoniæ*.

The facts already adduced most unequivocally demonstrate the arterial tubes to possess a high degree of vital contractility. But their active

* Neither Dr. Parry, nor Dr. C. H. Parry, has been able to detect alternate dilatation and contraction in the arteries when exposed. Since the appearance of Dr. Parry's publication, the author has, in numerous instances, attended to this circumstance; and the result of his observations is, that dilatation and contraction may frequently be seen. It is true that the artery, when exposed, is often quiescent; which appears to arise from some contraction of the vessel preventing the blood which is propelled by the heart from dilating it. Certain it is, however, that the author has frequently seen the arteries contract and dilate when exposed, and principally during the application of chemical or mechanical stimuli to them. He would feel almost afraid to maintain this controverted point on his single testimony, and is therefore happy to say that it is supported by that of several friends, who witnessed the experiments, and were satisfied that in many instances they saw alternate dilatation and contraction of the larger arteries. He begs here to return his best thanks to Drs. Brayne, Archer, Hawkins, and Osborne, who kindly assisted him in the above experiments.

agency is not only supported by such experiments as those related; it is also countenanced by an extensive series of phenomena presented during disease in the human subject. Of these may be mentioned irregular determinations of blood, the growth of tumors, increased pulsation of arteries leading to inflamed parts, of which the following is a well marked example, the accuracy of which may be entirely relied upon. The carotids, when the person alluded to is in health, beat equally as to strength and frequency; but when he is attacked with inflammation in the right tonsil, to which he is particularly subject, and which sometimes proceeds so far as nearly to prevent deglutition, each pulsation of the artery gives a throbbing sensation on the right side of the head. On the application of the hand at this time to each carotid, the right is found to beat much stronger and fuller than the left.

This diversity of action in these two arteries cannot arise from any impulse given to the blood by the heart; it must be derived from some modification of the contractile power of the artery. It is true that Dr. C. H. Parry wishes to attribute to the remote influence of the heart some of the phenomena of local congestion and motion; and to shew that the different states of vascular dilatation are still more conspicuously connected with the different degrees of action in the heart, and the consequent momentum of blood.

than with local circumstances ; and that the proneness to local dilatation, or, as it is called, action, is a consequence of slowly succeeding but continued impulse*.

But it seems impossible to grant such extraordinary powers to the heart ; and until the writer alluded to can bring forward more evidence in support of his opinions, few probably will coincide with him. If, however, he still retain the very improbable supposition that the influence of the heart produces some of the phenomena of local congestion and motion, he surely will never be bold enough to assert, that the difference in pulsation of the two carotids, in the instance alluded to, arose from the increased action of the heart.

The inference from all these facts seems to be, that there is sufficient evidence of the irritable power of the larger arteries. It has been shown that these vessels are obedient to chemical and mechanical stimuli, and that the effects arising from the application of these stimuli resemble those which they produce when applied to parts decidedly muscular ; and, therefore, it follows, that the larger arteries exhibit those vital phenomena which characterize irritability in muscular parts.

Plainly as this inference seems deducible from the preceding statement, yet on this, as on al-

* Additional Experiments on the Arteries, by C. H. Parry, M.D. F.R.S. Preface, p. 6 : and in the work, p. 112, 114.

most every point in medicine, we are doomed to meet with conflicting opinions. Certain pre-possessions, the apparent, though not real opposition of some facts, and an incautious mode of reasoning, have all had their share in obscuring the truth, and have given birth to objections. These, for the most part, have not much weight. There is one, however, which at first sight may impose on some minds : it is denied that there are any indications of irritability from the application of some stimuli. Bichat and Majendi both declare that they have only seen contraction from acid stimuli, which contraction they explain on chemical principles. This want of coincidence with the other writers on this subject is much to be regretted ; but still, if we are to put any confidence in those who have described at length their experiments, we must arrive at an opposite conclusion, and rely more on their affirmative than on Bichat and Majendie's negative experiments. Besides, neither Bichat nor Majendie gives a detailed account of his experiments, which, if fully narrated, might as well as Dr. Parry's, have been found to afford evidence against their own opinions. It should also be kept in view, that, in some instances, the stimulus may be applied a considerable time before any effect is produced. In two experiments made by the author, it was near an hour before any contraction took place in the artery. What also greatly lessens this objection, is the fact of our not always

being able to excite contraction in those parts which are allowed to be irritable. Verschuir relates instances* in which he applied electricity to the heart and bladder without any contraction arising from it; and Zimmerman† says he could not always excite by stimuli parts undoubtedly muscular. This shows us how cautious we should be in drawing inferences from those cases in which arteries are not immediately affected by stimuli.

Another objection has been made relating to the stimulants employed. It has been said by some writers, particularly by Bichat, that the effect of any acid stimulus is independent of the vital power; and he supports this opinion by saying, that alkalies produce no effect on the action of arteries. He has not however given any history of these experiments with alkalies. Results obtained by Dr. C. H. Parry, and by the author, which lead to a directly opposite conclusion, have been before noticed. But whatever weight be allowed to this objection, it will not apply to the examples brought forward in this essay, as in many instances the contraction arose from mechanical stimuli, or ammonia. Again, it appears that the objections adduced against acids is by no means well founded. In the cases in which the nitric acid was used the contraction of the vessel disappeared in a few hours; but the chemical effect on it,

* Verschuir de Arteriarum et Venarum Vi Irritabili, Exp. 22.

† Zimmerman de Irritabilitate.

and the parts around, continued some time afterwards*. Besides, from several experiments that will be related in the sequel, it will appear that no visible contraction arises in the vessels of dead animals from the acids, although they become white from their chemical action. From all these circumstances it is quite manifest that the chemical action and vital contraction are separate effects produced by the acid, which may, by an experienced eye, be readily distinguished. This may serve to show the inexpedience of urging the uncertainty of acid stimuli as an objection.

A recent writer seems to object to these vessels being considered irritable, although they obey chemical and mechanical stimuli; because he denies the efficacy of contraction and dilatation in producing the state of undisturbed circulation under the ordinary circumstances of life; or does not admit that the blood is a stimulus corresponding with those causes of chemical or mechanical irritation†. The question then, in the work of Dr. C. H. Parry, assumes a new shape. The father, in the experimental inquiry into the nature of the arterial pulse, maintains that the arteries are not irritable, because they are not affected by a great variety of chemical or mechanical agents called stimuli. The son, in his additional experiments, says, "We may be disposed to admit the

* See Table, Experiment 24.

† See Additional Experiments on the Arteries by Dr. C. H. Parry, p. 99, 124.

"possible production of such an effect, (contrac-
"tion from chemical or mechanical stimuli) but
"does this admission prove the blood to be a
"stimulus corresponding in its properties with
"those causes of chemical or mechanical irrita-
"tion*?" Again: "You may (by irritation) di-
"late permanently, or permanently contract the
"caliber; in either of which cases the phenomena
"of inflammation might occur; but these effects
"warrant no conclusions as to the powers by
"which the healthy conditions are maintained†."

This argument does not at all effect the point now in discussion; for if, as even Dr. Parry senior acknowledges, all parts are irritable which contract on the application of stimuli, Dr. Parry junior, when he admits that the arteries are affected by chemical and mechanical agents, can no longer, consistently with his father's views, deny that the arteries possess an irritable power; since tonicity, according to the definition of the term, is a mean state of contraction. Having once allowed that the arterial fibres are constituted so as to obey chemical and mechanical stimuli when applied to them, it would be arguing against all analogy to maintain that they are not affected by the blood that passes through the vessels; because no one will deny that the blood is both a chemical and mechanical stimulus, which is much more nearly applied to the fibres of the middle coat

* Additional Experiments, p. 124. † Page 126.

than any of the stimuli ever are, that are used in experiments on living animals; and in all other parts which are endowed with irritability, this property is subservient to some specific purpose. The irritable fibres of the heart are acted on by the blood. Those of the stomach and intestines obey their peculiar stimuli, as do also those of the urinary bladder. Why then should Dr. Charles Parry, who experimentally shows that the arteries possess the same irritability, deny that their fibres are affected by that stimulus which seems proper to them? or why should he suppose that Nature endowed them with this property, not to assist in preserving the undisturbed circulation in the ordinary circumstances of life, but to enable them to contract or shorten their fibres when any foreign stimulus is applied to them?

It should be distinctly understood, that it is by no means necessary for those who conceive that the arteries possess an irritable power to point out the mode in which their action influences the motion of the blood. A considerable degree of obscurity, indeed, still hangs over this subject, which is very desirable to have cleared up; but it is sufficient for their purpose to demonstrate that the arteries possess that property in no small degree; and the conclusion follows, that it serves some office in the circulation. Now surely this has been demonstrated; for it has been shown that an artery, on exposure to the air, will occasionally contract so powerfully as to become im-

pervious; thus, actually exerting a degree of contractile power exceeding the momentum with which the blood is propelled into it from the heart. It has also been evinced, that one effect arising from the application of chemical and mechanical stimuli is greatly to increase the pulsations of the artery, in which event contraction and dilatation become very perceptible. Again, Dr. Charles Parry himself admits that "when a ligature is placed on an artery, or any other interruption to the circulation takes place, the blood moves in a retrograde current."* Assuredly, by this admission, he attributes to the arteries a much greater power than that of tonicity; for by it he acknowledges that the force with which an artery contracts is such as entirely to overpower the action of the heart, and thus direct the blood in a current opposed to that in which it is propelled by that organ. The writer above mentioned endeavours to evade this obvious inference by a species of reasoning which does not appear at all admissable. "These cases," he observes, "however, like many others, if indeed they prove any thing with regard to this function, prove that the circulation is independent of the heart." This conclusion seems by no means logically accurate; for the author of the additional experiments undoubtedly does not wish to assert that the cir-

* See Additional Experiments, p. 102.

culation of the blood throughout the system, and the irregular motion produced in it by one vessel, are one and the same thing; and unless he does so, how can the experiment alluded to "prove "that the circulation is independent of the "heart?"

Will, then, the calm and unbiassed inquirer believe that, under circumstances such as have been stated, an artery exerts extraordinary contractile powers, and yet that in other circumstances, "the vessel itself cannot be considered "otherwise than as a comparatively passive "tube."* Will he not rather grant that, in ordinary states of the circulation, the arteries assist the heart, and promote the course of the blood?

To pursue the objections.—It has been argued by Dr. Parry, "that any alternate contractile "power, like that of muscular fibres in the arte-"rial system, beyond that which implies a mere "state of accommodation to the column of blood "actually impelled into any part of it by the vis "a tergo, would just as much tend to impede the "ingress of a new quantity of blood, as to pro-"mote the egress of that already existing in it; "and therefore could in no degree assist the cir-"culation."† But this opinion is grounded on a supposition that the ventricle, when it acts, has to overcome the contraction of the arteries, which

* Additional Experiments on the Arteries, p. 113.

† Elements of Pathology and Therapeutics, p. 20.

is not at all warranted by facts ; for there is much reason to believe, that the middle coat of the arteries is so constituted, that its fibres contract and relax in such a manner as to assist the heart, and promote the course of the blood. It would therefore be almost as consistent with sound logic to contend that the contractile power of the ventricle is an obstacle to the flow of blood from the auricle, as that the same power in the arteries is an impediment to the blood which is propelled into them from the ventricle.

II. Having noticed the objections that may be made to the obvious inference that presents itself, from a review of the evidence adduced in favour of the irritability of the arteries, the phenomena which may be observed in the capillary vessels shall now be described. These seem to demonstrate that the smaller vessels possess an equal, if not greater degree of contractile power than the larger arteries.

Haller, who allowed, as has been before noticed, some degree of irritability in the larger arteries, altogether denied the existence of any such property in smaller vessels. It appeared to him quite inconsistent to call these vessels irritable, since he had never seen them contract.* But

* Sed delentur etiam omnia, qu à vi irritabili et oscillatione vasorum minimorum clari viri expectarunt. Si enim arteriæ minores non contrahuntur, sequitur neque irritabiles

this objection by no means satisfied Professor Whytt. It did not escape his penetrating mind, that although no pulsation could be detected in these vessels, yet a variety of facts clearly proved their vital action. Local stimuli cause local inflammation: shame produces blushing. He also adduces the striking circumstance of the flow of saliva in hungry persons, the flow of tears by acrid applications to the eyes, the irregular oscillatory motion of the blood in the smaller vessels, none of which effects, he conceives, can arise from the action of the heart; but they receive a ready explanation by admitting the existence of a vital contractility in the smaller vessels.* John Hunter, in his work on inflammation, relates several experiments on the arteries of dead animals, which seem to him satisfactorily to prove that the small vessels are more muscular than the larger arteries.† Bichat's opinions concerning the capillary vessels differ from all those who preceded him. He attempts to demonstrate that the impulse given to the blood by the heart does not extend to the capillaries, and consequently attributes its motion in those minute tubes to a vital power of contraction proper to them. This faculty he calls insensible organic contractility, or tonicity; which term, as has been

esse, neque sanguinis iter promovere.—*Halleri Elementa Physiologiæ*, tom. ii. p. 212.

* Whytt on the Motion of the Fluids in the small Vessels.

† Hunter on the Blood, Inflammation, &c.

already observed, he uses to designate a low degree of irritability*. But none of the writers hitherto mentioned were enabled to discover an increased action from the application of stimuli. It was reserved for Dr. Wilson Philip, by experiment, to correct the error into which Haller led his followers, by denying the contractility of the minute vessels. In the introduction to his treatise on febrile diseases, he relates several instances in which the application of spirit of wine to the web of the frog's foot increased the velocity of the circulation in that part†. Dr. Thomson has also brought forward several examples, in which a contraction was caused by the application of ammonia to the capillary vessels of the same animal‡. These experiments receive further confirmation by the facts lately detailed by the former writer in his treatise on the vital functions. He there confirms the observation made by Haller and Bichat, that the circulation in the smaller vessels continues for some time after the heart is removed. But what is still more satisfactory, he seems, by the 29th and 30th experiments, to have proved that the capillaries obey stimuli applied to the brain and spinal marrow.

* Dans le système capillare générale la contractilité organique insensible, ou la tonicité, reste seul pour cause de mouvement du sang.—*Bichat Anatomie Générale.*

† Wilson Philip on Febrile Diseases.

‡ Thomson on Inflammation, p. 83.

Nothing can be more satisfactory in evincing the existence of an irritable property in the capillaries than the authorities which have been adduced ; yet, notwithstanding all this weight of evidence, many writers of the present day will not admit any such vital faculty in these vessels ; and in their pathological inquiries overlook the diseased action of the capillaries, which often forms an important link in the chain of morbid phenomena. Therefore the following observations, made on the smaller vessels to ascertain their contractile powers, may be here detailed.

In the transparent parts of animals we have, by aid of the microscope, a very good view of the circulation, and are enabled to trace the ramifications of the arteries till they become small capillary tubes ; and these again, till they gradually enlarge into venous trunks. It requires much practice, however, in the use of the microscope before any dependence can be placed on the experiments of the most careful observer. It is the more necessary to insist on caution in drawing conclusions from this kind of experiment, because so many causes may disarrange the natural order of the circulation ; and thus a casual occurrence may be mistaken for the usual course of the phenomena. Alive to the numberless obstacles which might oppose this investigation, the author has never considered any new appearance as entitled to be relied upon, until repeated examinations had narrowed, as far as possible, the field of error.

These experiments were principally made on the web of the frog's feet, because the animal suffers little from being enclosed in a linen bag, and having its foot fastened in the field of the microscope, by which a good view of the vessels is obtained. Before commencing the experiments, it was necessary to become familiar with the circulation in the web, which in ordinary circumstances is effected as follows :—Large arterial and venous trunks run along the toes. On the web itself the arteries ramify in a beautiful manner, and communicate with each other by frequent anastomoses. They generally divide into myriads of minute vessels, which are seen in every part of this delicate membrane. These capillary tubes may at length be observed gradually to enlarge : and ere long small venous trunks appear ; these are for the most part larger than the arteries, twice as numerous, and they more freely communicate with each other, and with the capillaries ; which latter vessels might not improperly be called a venous net-work. The arteries, however, do not invariably divide into very minute tubes : it occasionally happens that a large arterial trunk communicates directly with the venous vessel, and pours its blood into it.

With regard to the appearance of the blood in the vessels, it may be remarked that small globules float in a serous fluid. These globules approach much nearer to each other in the arteries and veins than in the capillaries. The most minute of these

last vessels admit only one globule at the same time; and a considerable space intervenes between them, in which space serous fluid is alone observable. The globules are not moved on their axis, nor do they appear to change their figure whilst passing through the innumerable circumvolutions and windings of the vessels. It is difficult to give a precise idea of the colour of the blood, because it is much altered by the degree of the intensity of the light; but the blood in the veins, which nearly accords with Werner's tile red, is the darkest; that in the arteries ranks next in deepness of colour; and last of all the capillaries, in which, when the light is very bright, the globules appear almost pellucid. From frequent observations on these three orders of vessels, it was found, when the leg was so placed as to allow every part of the animal to be free from pressure, and the action of the heart undisturbed, that the blood moved with considerable rapidity, and in an uninterrupted stream. Indeed this mode of observation is so convenient, and productive of so little pain to the frogs, that for an hour together the globules may be seen flowing with rapidity through a series of convoluted vessels, without manifesting any sensible impulse during the contraction of the ventricle; the blood always moving faster in the arteries than in the veins, and faster in the veins than in the capillaries.

Those phenomena which present themselves when the natural order of the circulation is disturb-

ed, shall next be described. The means which were employed to interrupt the ordinary motion of the blood, were,

1. By the external pressure of the limb.
2. By ligature applied to the small vessels.
3. By ligature placed on the great vessels, or excision of the heart.
4. By the application of stimuli to the minute vessels.

1. *External Pressure of the Limb.*

EXPERIMENT.

A frog's foot was brought into the field of a microscope, and the circulation observed for some time. The blood was moving in an uninterrupted current through the numberless vessels in the web. A ligature was thrown round the limb. The motion of the blood became much slower: and a sensible impulse was given to it in the three orders of vessels at each contraction of the ventricle. In several other instances a similar result ensued.

EXPERIMENT.

Considerable pressure was applied to the limb of a frog, the circulation having been previously observed to be in a natural state. The effect of

the pressure was to cause the blood to move slower; and in one large vein, an oscillation, that is, a moving backwards and forwards of the blood, took place for some minutes. The oscillation of the blood in the vessels of the web was seen in numberless other instances.

EXPERIMENT.

The circulation was observed to be perfectly natural. A ligature was then drawn very tightly on the limb of a frog. In one artery the blood took a retrograde direction, and flowed in a brisk current towards the large trunks. At the same time, in one large vein, and in the minute ramifications into which it divided, the blood took an opposite current to that in which it had been before moved, flowing, in a quick uninterrupted stream, from the trunk towards the branches; so that the vein and its ramifications resembled arterial tubes. This phenomenon continued for five minutes, when the pressure was removed, and the blood resumed its accustomed current. These appearances were verified in several other examples.

The conclusions to be drawn from these experiments appear interesting. From the first we learn, contrary to what has been maintained by Bichat and some other physiologists, that the action of the heart influences the circulation in the

cappillaries, and that it even extends to the veins*. For in what other way can we account for the sensible impulse given to the venous blood at each systole of the ventricle, but by supposing that the impetus given to the mass of blood was felt in these tubes ?

The results of the two last experiments particularly deserve the reader's attention. They prove that the contractile power of the minute vessels is capable of producing irregular motion in the blood without any assistance from the heart. In one of them, a ligature being drawn very tight round the limb, the blood flowed very briskly, in a direction opposed to that it would have taken if put in motion by the contraction of the ventricle, and in the other the blood moved to and fro in the vessels without making any progression†.

2. This power of the small vessels to produce motion in the blood independent of the heart, appears also from the effect of obstruction to the flow of blood through them, as demonstrated by the following experiment :—

* See Thomson on inflammation, in whose experiments, similar results occurred.

† See Dr. Philip's Essay on the Vital Functions, and Dr. Thomson on Inflammation, in which works similar results are recorded.

EXPERIMENT.

The motion of the blood was observed for a considerable time in a large vein of a frog's foot, which emptied its contents into a still larger vessel running along the middle toe. The blood in it flowed with considerable celerity and in an uninterrupted stream, from the branches towards the trunk. The vein was transfixed with a needle, which prevented the blood passing on in the accustomed current. No accumulation of blood took place; it immediately took an opposite direction, and flowed with as much celerity towards the veins of the opposite toe as it had previously done in the contrary direction. This experiment was repeated several times, and was witnessed by several persons.

3. But of all the facts which prove a contractile power in the small vessels, none are more satisfactory than those which show that the circulation continues after the heart is removed. In several instances the author has known the blood move for a quarter of an hour after the removal of the heart*. But the circulation in this case is often as irregular as when pressure is applied to the limb

* Dr. Philip saw the circulation continue with regularity in the mesentery of a rabbit for a half an hour after the excision of the heart.—*Essay on the Vital Functions, 2d Edit.*

or body before the heart is taken away. The blood oscillates in the arteries, and in the veins takes a retrograde current. The oscillation of the blood in the arteries and its retrogression in the veins, in such instances is a strong argument, against the hypothesis of Dr. Parry: who, in his work on the pulse, supposes that the motion of the blood after the removal of the heart receives a ready explanation from the gradual contraction of the larger arteries.

4. The effects produced by the application of stimuli to the minute vessels may now be stated.

EXPERIMENT.

The circulation in the web of a frog's foot was observed, and found natural. There was an artery running across the web from the middle toe, and dividing into capillaries. This vessel was touched with liquor ammoniæ. The blood in the capillaries to which it terminated soon moved slower. In two minutes the artery was contracted, and the motion of the blood through the contracted part was quickened at each systole of the ventricle, whilst the capillaries were somewhat dilated. In about four minutes the blood in the artery moved slower, and the contraction was increased—indeed so much increased, that this vessel was scarcely larger than the capillaries had been in the beginning of the experiment. In seven minutes the

artery and its ramifications continued as before, whilst in all other parts of the web the circulation was natural. In eight minutes the artery became nearly of its former size, and the motion of the blood as it had been before the contraction of the vessel, with the exception that it was occasionally quickened by the contraction of the ventricle. The dilatation of the capillaries continued.

EXPERIMENT.

The web of a frog's foot was brought into the field of the microscope, and the blood observed flowing through the vessels in an uninterrupted stream. There was one large vein running across the web, and to this vessel oleum terebinthuæ was applied. In about ten minutes from the first application of the stimulus, the vein began to contract; in twenty minutes, its size in one point was very much diminished; and beyond the contracted part, an evident impulse was given to the blood at each systole of the ventricle; although at the same time, it moved on in an uninterrupted stream in the vessels of every other part of the web. In thirty minutes, the contraction had so much increased that the vein at that part was impervious.

No accumulation, however, of the blood happened; for as soon as the diminution of the main

trunk was such as wholly to prevent its passage, it took a retrograde course in one of the larger branches, and thus the fluid was diverted from its wonted channel, and was distributed to the large veins on the opposite side of the web. The circulation continued in this direction for five minutes, at which period a small quantity of blood passed through the narrowed part at each contraction of the ventricle. This irregular propulsion of the blood continued but a short time; for suddenly the contraction vanished, and then the circulation in the vein and its branches returned to the state it had been in before the oil of turpentine was applied. It was not noted in what manner the capillaries were affected in this experiment.

EXPERIMENT.

A frog's web being brought into the field of the microscope, the circulation was observed to be natural. Spirit of wine was spread over all that part of the web which was contained between the two outer toes, and the part of the web between the inner toes was untouched. In one minute after the application, the velocity of the blood's motion in that part of the web to which the spirit was applied increased, whilst the circulation in the part of the web which was untouched remained as at first.

EXPERIMENT.

After having observed the circulation in the web of a frog's foot, liquor ammoniæ was spread over the whole of it. In five minutes all the vessels were dilated, the blood became deeper coloured and moved very slowly.

EXPERIMENT.

The circulation was first noticed, as before. A saturated solution of muriate of soda was spread over the whole web of the foot. In three minutes the arteries, veins, and capillaries became much dilated, the blood deeper coloured, and the globules scarcely visible. The blood moved slowly, and the web was rendered somewhat opaque. In five minutes the web was washed with spirit of wine. In two minutes afterwards, all the vessels were sensibly diminished in size, and the blood moved faster. At the end of a quarter of an hour, the vessels had contracted to their former size, and the circulation became in every respect as when first observed.

EXPERIMENT.

The circulation in the web of a frog's foot being first attended to, and the foot then immersed in

water, heated to 115 degrees of Farenheit's scale, for half a minute, the motion of the blood was immediately quickened, and the vessels in some degree contracted. The immersion was repeated with the same effect. After the foot had been immersed five times in water of the temperature as above, the vessels were much dilated, the blood became redder, moved slowly, and no globules could be seen; but it appeared converted into a red mass. After the vessels had continued in this state for twenty-five minutes, ice was applied to the web. The vessels in about a quarter of an hour again contracted, the globules re-appeared, and the natural motion of the blood was restored.

EXPERIMENT.

Ice being applied to the web of a frog's foot, in five minutes the motion of the blood increased, and the vessels contracted; but at the end of half an hour, during which time the ice was kept to the web, the vessels were dilated, the blood became redder, and circulated more slowly. Oleum terebinthinæ was now spread plentifully over the web. In ten minutes some of the vessels evidently contracted from the contact of the oil, and in them the motion of the blood acquired its former velocity. Many vessels, however, did not contract,

but remained dilated with blood, which scarcely moved.

In the foregoing account of the effects of stimuli applied to the minute vessels, a particular description of the most important experiments has been given, in order that the circumstances under which they were made may be clearly understood. The leading circumstances of the remainder are given in the annexed Table.

TABLE II.

	Stimulus.	*Part to which it was applied.*	*Effects produced.*
1	Liquor Ammoniæ .	Artery of the Web	In 2 minutes a contraction was produced, which lasted 7 minutes.
2	Liquor Ammoniæ .	A Vein of the Web	In 4 minutes contraction came on, and lasted 2 minutes.
3	Liquor Ammoniæ .	A Vein of the Web	No contraction.
4	Liquor Ammoniæ .	A Vein of the Web	No contraction.
5	Liquor Ammoniæ .	A Vein of the Web	Slight contraction came on.
6	Liquor Ammoniæ .	A Vein of the Web	No contraction.
7	Liquor Ammoniæ .	A Vein of the Web	No contraction.
8	Liquor Ammoniæ .	A Vein of the Web	An evident contraction was produced.
9	Liquor Ammoniæ .	A Vein of the Web	So great contraction that globules scarcely passed.
10	Liquor Ammoniæ .	A Vein of the Web	Considerable contraction produced in 2 minutes.
11	Liquor Ammoniæ .	A Vein of the Web	In 6 minutes contraction produced.
12	Liquor Ammoniæ .	Over the whole Web	In 5 minutes arteries, veins, and capillaries were much dilated.
13	Liquor Ammoniæ .	Over the whole Web	The same result.
14	Liquor Ammoniæ .	Over the whole Web	Nearly a similar result.
15	Liquor Ammoniæ .	Over the whole Web	The vessels in general much dilated, one vein contracted.
16	Oleum Terbinthineæ	To an Artery	In 25 minutes the artery for some extent was much contracted.
17	Alcohol . .	To the whole Web	The motion of the blood quickened.
18	Alcohol . .	To the whole Web	The same result.
19	Prussias Potassæ .	To a Vein . .	No effect produced.
20	Prussias Potassæ .	To a Vein . .	No apparent effect.
21	Prussias Potassæ .	To a Vein . .	Slight contraction.
22	Oxide of Arsenic .	To an Artery . .	No contraction excited.
23	Oxide of Arsenic .	To a Vein . .	No contraction excited.
24	Opium . . .	To an Artery . .	Did not produce any effect.

TABLE II. *(Continued.)*

	Stimulus.	*Part to which it was applied.*	*Effects produced.*
25	Tinctura Lytæ . . .	To an Artery .	In half an hour some contraction came on.
26	Tinctura Lyttæ . . .	To a Vein . .	No contraction.
27	Tinctura Lyttæ . . .	To a Vein . .	In half an hour slight contraction.
28	Acetic Acid, with equal parts of water	To an Artery .	In a minute the vessel was considerably contracted.
29	Acetic Acid, with equal parts of water	To a Vein . .	The vessel contracted so much that the blood flowed in a retrograde direction.
30	Acetic Acid, with equal parts of water	To an Artery .	Contraction produced.
31	Acetic Acid, with equal parts of water	To a Vein . .	The same result.
32	Saturated Solution of Muriate of Mercury	To a Vein . .	Two hours application produced no effect.
33	Saturated Solution of Muriate of Ammonia	To an Artery .	In 5 minutes a contraction came on.
34	Saturated Solution of Muriate of Ammonia	To a Vein . .	Contraction excited, and the blood moved in jets.
35	Saturated Solution of Muriate of Ammonia	To a Vein . .	Dilatation of the vessel and the capillaries connected with it came on; in 5 minutes, by the application of spirit of wine, the vessels contracted.
36	Saturated Solution of Muriate of Ammonia	To the whole Web	All the vessels became dilated.
37	Saturated Solution of Muriate of Ammonia	To an Artery .	A contraction caused.
38	Saturated Solution of Muriate of Ammonia	To the whole Web	General dilatation of the vessels; after which spirit of wine was spread on the web, and soon after the vessels contracted.
39	Saturated Solution of Muriate of Ammonia	To the whole Web	All the vessels soon dilated, the web became opaque; at this period alcohol being applied, the vessels were caused to contract.
40	Saturated Solution of Muriate of Ammonia	The whole Web	Dilatation of all the vessels; in a few minutes, spirit of wine being applied, the vessels again contracted.
41	Saturated Solution of Muriate of Ammonia	The whole Web	The solution produced general dilatation of the vessels; ice was then applied, and speedily the vessels became contracted.
42	Nitrous Acid . . .	A Vein . . .	web was so discoloured that the effect on the vessel could not be seen.
43	Tinctura Opii . . .	The whole Web	Circulation of the blood quickened.

It now only remains to point out the conclusions concerning the vital contractility of these vessels which the facts stated obviously lead to.

It appears that the application of a stimulus often quickens the circulation in the small vessels, whilst the motion of the blood in a neighbouring part, to which no stimulus is applied, remains unaffected.

That when a small vein or artery is touched by a stimulating substance, a contraction is often produced, so as to be visible by the help of the microscope. This contraction sometimes proceeds to such an extent as to prevent the free passage of the blood; and in this case it does not accumulate, but takes a retrograde course. During such contraction, if not sufficient to prevent the transit of blood, the impulse of the ventricle is generally perceptible in all the vessels in communication with the contracted one, and the blood in the capillaries connected with the contracted vessel for the most part moves slower.

That a stimulus, in the first instance, often produces a quick motion of the blood and contraction of the vessels; but after it has been applied some time, dilatation of the vessels and a slower movement of the blood follow; but after the vessels are dilated by the action of one stimulus, some other stimulus will often produce contraction.

That the action of water, heated considerably above the temperature of the animal to which it

is applied, often occasions contraction of the vessels and acceleration of the blood's motion; but after a certain time, dilatation and retarded circulation ensue. Ice generally produces a contraction of these dilated vessels, and restores the velocity of the circulation.

The ice kept in contact with the web of a frog's foot produces, in the first instance, a contraction of the capillaries, and increases the motion of the blood; but after a certain period, if the application be continued, the vessels become dilated, and the blood moves slowly. A temperature of eighty degrees of Fahrenheit, however, or the application of oleum terebinthinæ, again excites the capillaries to contract, and the circulation is restored to its natural state.

When the foregoing facts, and the necessary conclusions to which they lead, are maturely considered, it will be admitted that the capillaries possess a very considerable degree of irratability.

III. Therefore, those appearances may now be noticed which favour the supposition that the veins are not devoid of an active contractility. In the experiments which have been already fully detailed, several are related in which, by the microscope, the contraction of small veins was rendered evident. Inquiries are now to be extended to veins of a much larger size.

Haller and many other physiologists have con-

fined the irritability of veins to those trunks that are near the heart, on which muscular fibres are very plainly developed. Verschuir, however, could not conceive it was at all probable that the irritable power was confined to the venæ cavæ and the four pulmonary veins.* From his experiments he concluded that there is a contractile power in the whole venous system; although he believed the veins possess this property in a less degree than the arteries.

In corroboration of these experiments, the following, which were made by the author, may be related;—

EXPERIMENT.

The thorax of a cat being opened, no pulsation of the pulmonary veins was observed; but nitrous acid being applied to one trunk, it and all its branches were much contracted.

* Minimè vero probabile est principium irritabile esse datum solis venis cavis, et pulmonalibus, cùm et in variis illius ramis contractionis indicia detecta sunt; hanc rem in venæ cavæ propaginibus jam observavit in gallinis Lancisius doctissimus: quoque M. Van Geuns in venâ jugulari manifestam contractionem, propellentem sanguinem ad cordis sinum, expertus fuit, quod et ego manifestè confirmatum vidi; nec reliquas etiàm venas ad stimuli applicationem semper inertes inveni, adeó ut illis omninó non propriam vim contrahendi ad stimulum négare audeam, icet credam ipsis illud, minori gradu quam arteriis inesse.—*Verschuir De Arteriarum et Venarum Vi Irritabili.*

EXPERIMENT.

Nitrous acid was applied to the abdominal cava of a cat. Immediately the vessel was violently contracted. The thorax being afterwards opened, the acid was put on the vena cava near the heart, which produced a slight contraction.

EXPERIMENT.

The abdomen of a dog being opened, and the cava touched with acid, no contraction ensued; but the external jugular vein and a mesenteric vein evidently contracted from the application of the sam e stimulus: but thethoracic cava being exposed, and touched with the acid, no contraction occurred.

EXPERIMENT.

One of the large veins in a rabbit's ear was bared, and the acid applied. The vessel, in conquence, became so contracted that the blood could scarcely pass.

EXPERIMENT.

A vein in a rabbit's ear was exposed, and irritated with a scalpel, but no contraction ensued; and though, in several other instances, this mode of irritation produced no effect on the vessel, yet, in ten instances, contraction in the veins in the ears of rabbits was seen from the irritation of the denuded vessels with the scalpel.

These results are sufficient to show that the veins are not insensible to stimuli, though certainly it appears that they are not so readily affected by mechanical stimuli as the arteries are; from which it may fairly be concluded, that they possess a lower degree of contractility.

Some may think these experiments on the veins inconclusive, because in several of them the nitrous acid produced the contraction, which they may contend is a chemical effect. It must be confessed that this objection carries with it plausibility; but the experiments which are now to be related seem completely to obviate the difficulty. If it is supposed that the contraction from the acid is independent of the vital power, it must be allowed that it will take place to as great an extent after death as during the life of the animal. This, however, does not happen, as will appear from the following experiments :—

EXPERIMENT.

Nitrous acid was applied to six of the mesenteric veins of a dog which had been dead more than twenty-four hours. The vessels did not contract, although they became white from the action of the acid. The same experiment was tried in another dog, forty-eight hours after death, and with the same result. It was repeated a third time, on a dog which had been dead seventy-two

hours, and also in several other cases. In all the instances the veins were corrugated; but no sudden contraction, at all like that which happens from the application of the acid in living animals, was ever produced, provided the trial was made not less than twenty-four hours after the apparent death of the animal; for, until that period had elapsed, the acid produced a sensible contraction of the vessels; which may be attributed to their not having then wholly lost their vital powers.

It does not appear at all necessary to follow up the present inquiry by enumerating many other facts, equally strong, in support of the irritability of the blood vessels. The general results of the investigation shall therefore be stated.

1. The blood vessels, through every part of the system, possess a considerable share of irritability, by which they contract and propel forward their contents. Hence the blood, by the action of the vessels, receives a new impulse in the most minute tubes, and a well regulated momentum is preserved in every part of its course. But of all parts of the sanguiferous system, the capillaries seem most eminently endowed with this faculty, and are least indebted to the presiding influence of the heart. Yet even in these vessls we can, with the fullest confidence, maintain that the action of the heart is of consequence to sustain the healthy circulation; inasmuch as it gives the first impetus to the blood, and preserves the harmony of the sanguiferous powers.

2. The vessels are endowed with this vital property, in order that each organ in the body may receive such a supply of blood as will enable it duly to exercise its functions. It must therefore be evident, that a healthy state of this property is absolutely necessary for the preservation of the animal functions; for if the vital contraction of the blood vessels be either increased or diminished, irregular distribution of the blood inevitably follows, and from this fruitful source numerous diseases arise: none certainly more frequently than inflammation, into the nature of which we shall presently inquire.

But as some of the phenomena of this disease depend upon the intimate connexion between the sanguiferous and nervous systems, some facts on this subject shall be first briefly stated.

It is now an established principle that the action of the heart and blood vessels is independent of the nervous system*. This is abundantly proved by facts. If we take away the spinal cord and brain, the circulation continues for some time in full force. If we remove the heart from the body, it contracts with vigour and alacrity. But although the heart can continue to propel the blood after the removal of the brain and spinal marrow, yet certain states of the nervous system are known to produce effects on the action of the heart. Thus the passions affect the sanguiferous system; spirit of wine

* Dr. Wilson Philip on the Vital Functions.